

# MSI Z390 Overclocking Guide – Push Core i9-9900K Over 5GHz & Memory to 4000MHz

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## Get prepared for overclocking i9-9900K

Intel has just launched its 9<sup>th</sup> GEN processors, along with new Z390 chipset. Core i9-9900K, i7-9700K and i5-9600K are introduced to the lineup. Compared to 8<sup>th</sup> Gen processors, Intel has increases the core numbers to compete AMD. Core i9-9900K has 8 cores and 16 threads!

MSI has introduces Z390 motherboards for the new 9<sup>th</sup> Gen processors too. Here we're sharing how to overclock Core i9-9900K to 5.0GHz+, and overclock memory to 4000MHz with MSI exclusive "Dragon Alliance Mode" on MEG Z390 ACE.



### What is overclocking?

Overclocking means push the frequency of computer components higher than its stock frequency, and make it faster and have better performance. You can overclock major components of your computer, like CPUs, memory or graphics cards.

However, it always has risks to overclock. It may damage your components or make your system unstable.

**Try at your own risk.**

*Solder TIM is used for Intel 9<sup>th</sup> Gen processors and they have higher turbo frequency than 8<sup>th</sup> Gen processors.*

## Solder TIM for 9<sup>th</sup> Gen processors

Intel 9<sup>th</sup> Gen processors include i9-9900K, i7-9700K and i5-9600K. All of them are overclockable. And compared to 8<sup>th</sup> gen processors, the 9<sup>th</sup> gen processors use Solder Thermal Interface Material (STIM) instead of 8<sup>th</sup> gen processors' thermal paste. It's expectable that the 9<sup>th</sup> Gen processors have better heat dissipation and have better overclocking capability. Thanks to the STIM, Core i9-9900K has the max turbo frequency clocked at 5GHz.

Though i9-9900K has better overclocking headroom, it still generates lot of heat when overclocked, especially if you're running AVX workload, like AVX-compliant Prime95. It's very important to take care of the heat.

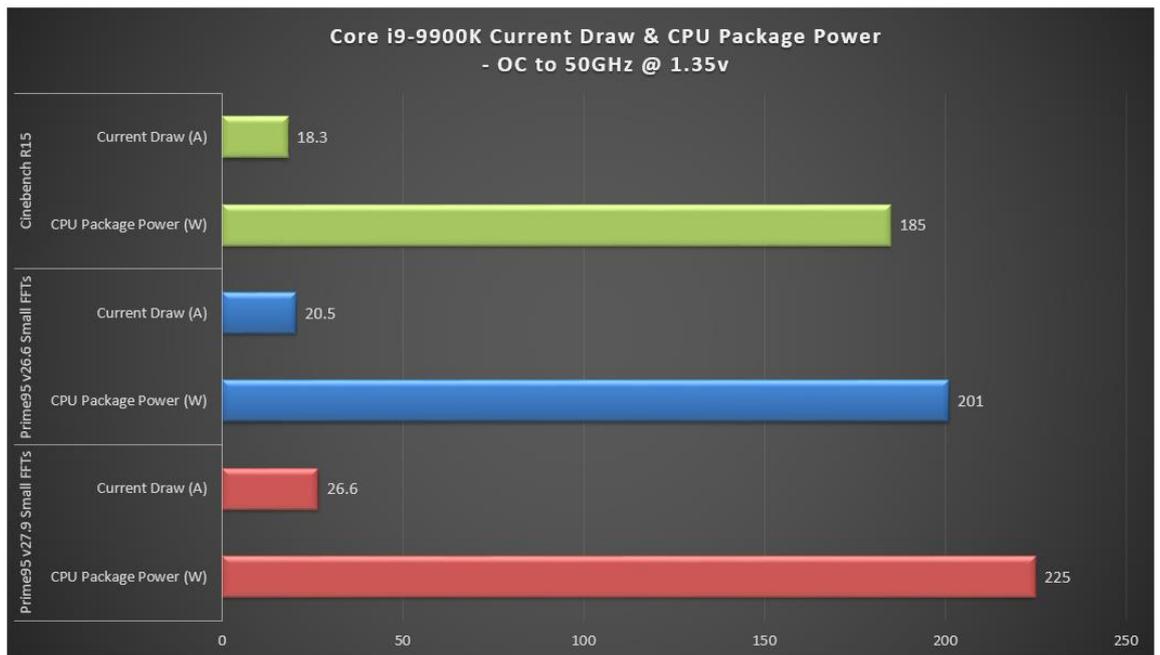
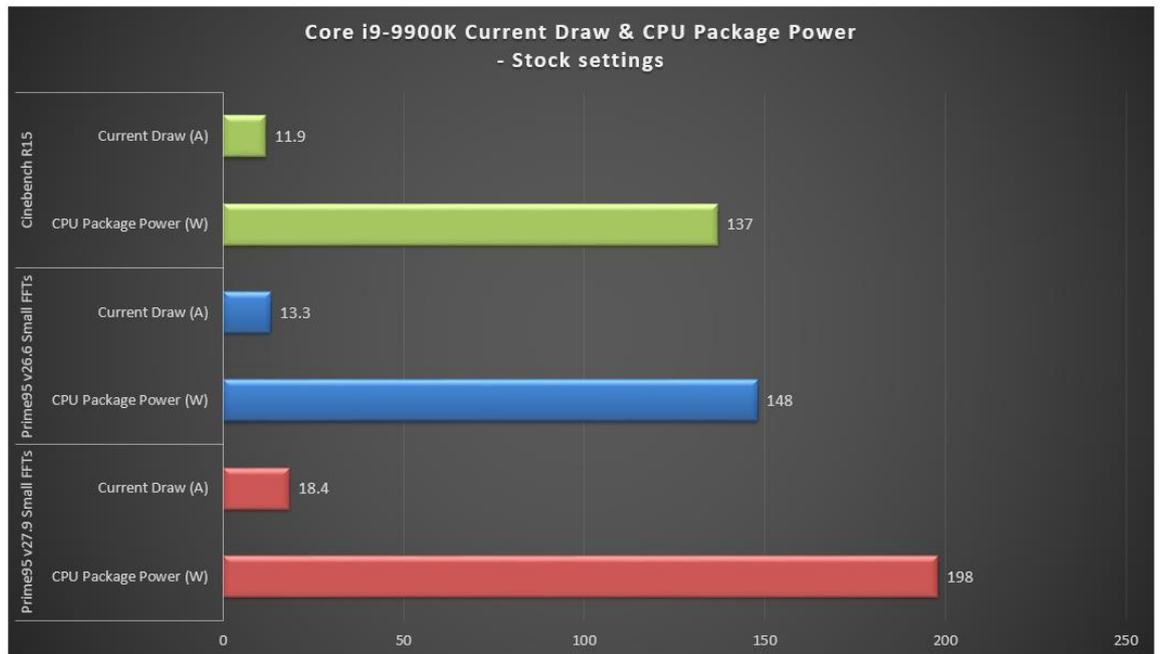
*650W+ PSU with 12V rail current higher than 30A is recommended.*

## Powerful CPU cooler and PSU recommended for overclocking

It's not hard to overclock i9-9900K to 5GHz or higher. But i9-9900K draws lot of current and it's a heat generator when overclocked. A powerful liquid cooler is strongly recommended, especially if you're running AVX workload like Prime95 Stress Test.

Besides powerful CPU cooler, you also need a premium power supply unit (PSU) to support i9-9900K power draw. The charts below show the current draw and CPU package power from a stock i9-9900K and i9-9900K overclocked to 5GHz.

As you see, stock i9-9900K draws 18.4A current through CPU power connector from the PSU with AVX Prmie95 Small FFTs. It draws 26.6 A from i9-9900K overclocked to 5GHz. So you need at least 650W PSU with the 12V rail current higher than 30A, if you plan to overclock.



*If your plan to overclock i9-900K to 5.0GHz+, a Liquid Cooler with 360mm or 280mm radiator is recommended.*

## Use liquid cooler with 240mm radiator at least

CPU cooler is very important for overclock i9-9900K. We recommend a liquid cooler with at least 240mm radiator (or 2x 120mm fan). But if you're doing 5GHz+ overclock and heavy workload tests, you'll need a liquid cooler with 360mm radiator (or 3x 120mm fan) or 280mm (2x 140mm) radiator.

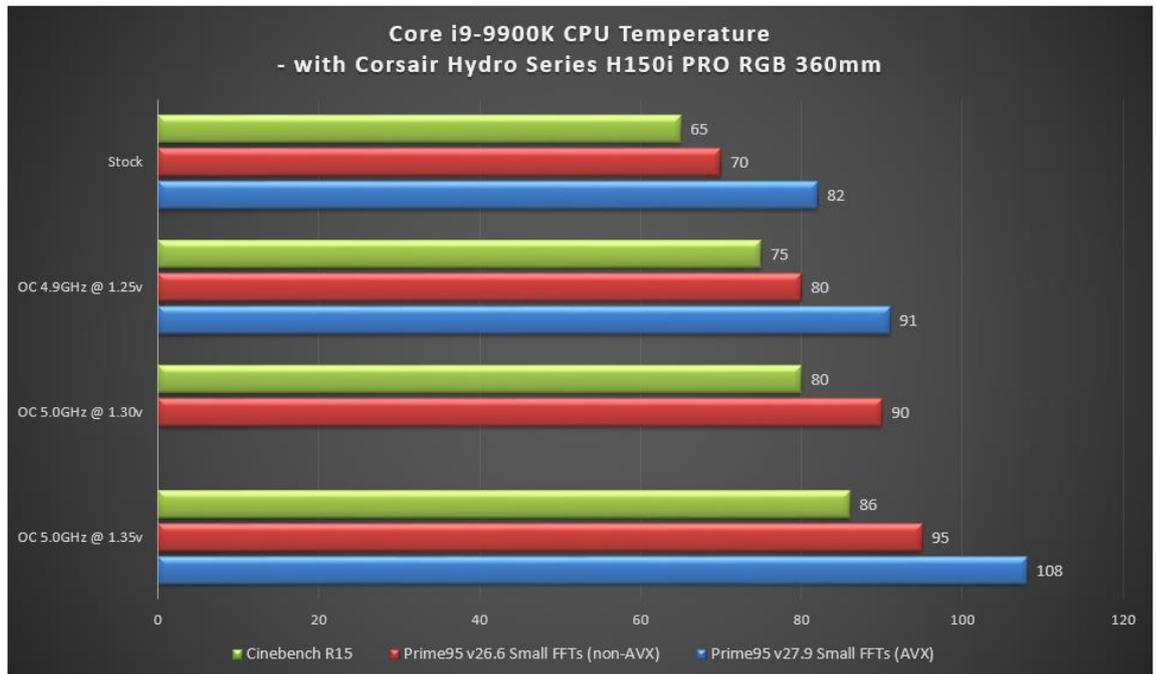
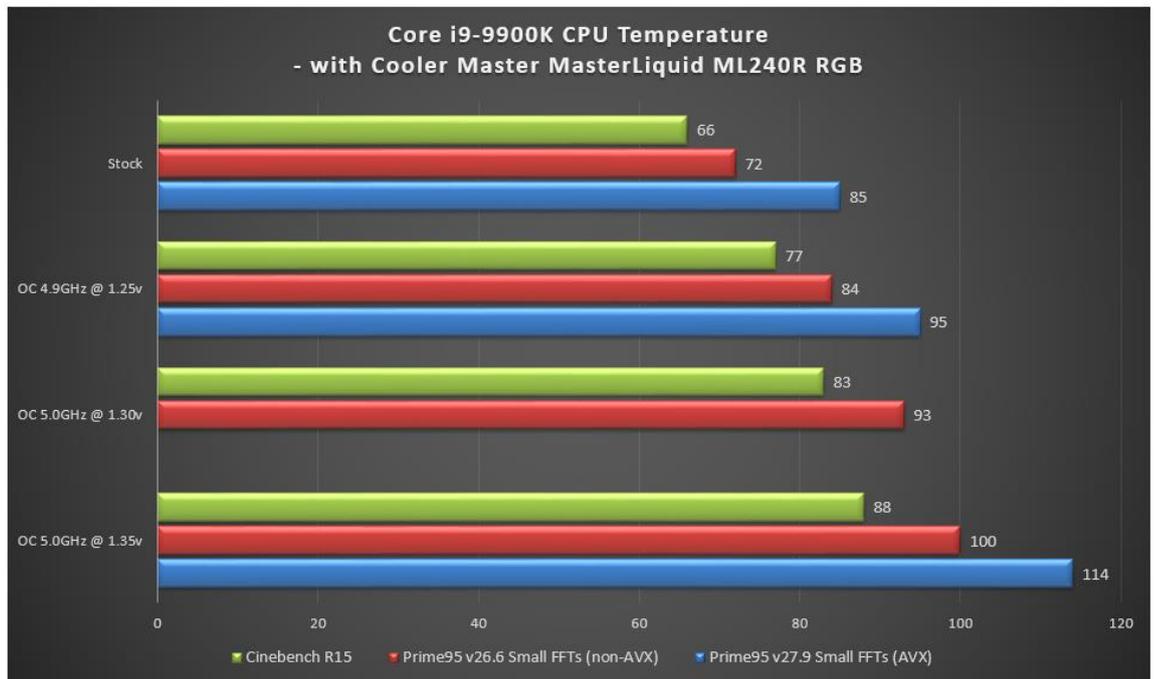
What CPU cooler to pick is depending on your demand. If you're not ambitious, less than 5GHz is good for you, a liquid cooler with 240mm radiator (2x 120mm fan) is enough. If you're eager for high frequency and 5GHz+ with heavy workload is your target, then you need a cooler with 360mm radiator (3x 120mm fan) or 280mm radiator (2x 140mm fan).

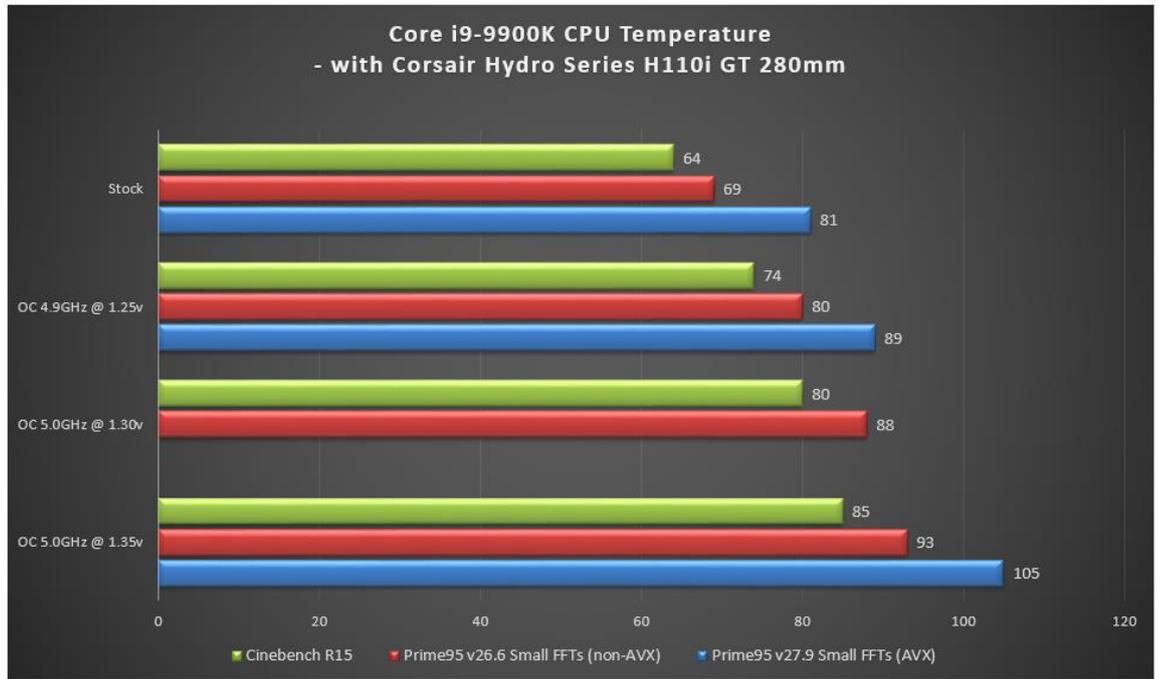
We've tested high-end Corsair H150i PRO RGB 360mm, H110i GT 280mm, and Cooler Master ML240R RGB (240mm) with i9-9900K. As you see from the chart, ML240R offers sufficient dissipation for a stock i9-9900K and 5GHz at 1.30v with non-AVX load.

But if you'd like to push more on i9-9900K or run AVX workload, 360mm /280mm is recommended.

### Recommended CPU cooler for i9-9900K overclock:

Scenario	Recommended Cooler specs
OC 4.9GHz and less	Liquid cooler with 240mm radiator (2x 120mm fan)
OC 5GHz and more	Liquid cooler with 280mm or 360mm radiator (2x 140mm fan or 3x 120mm fan)

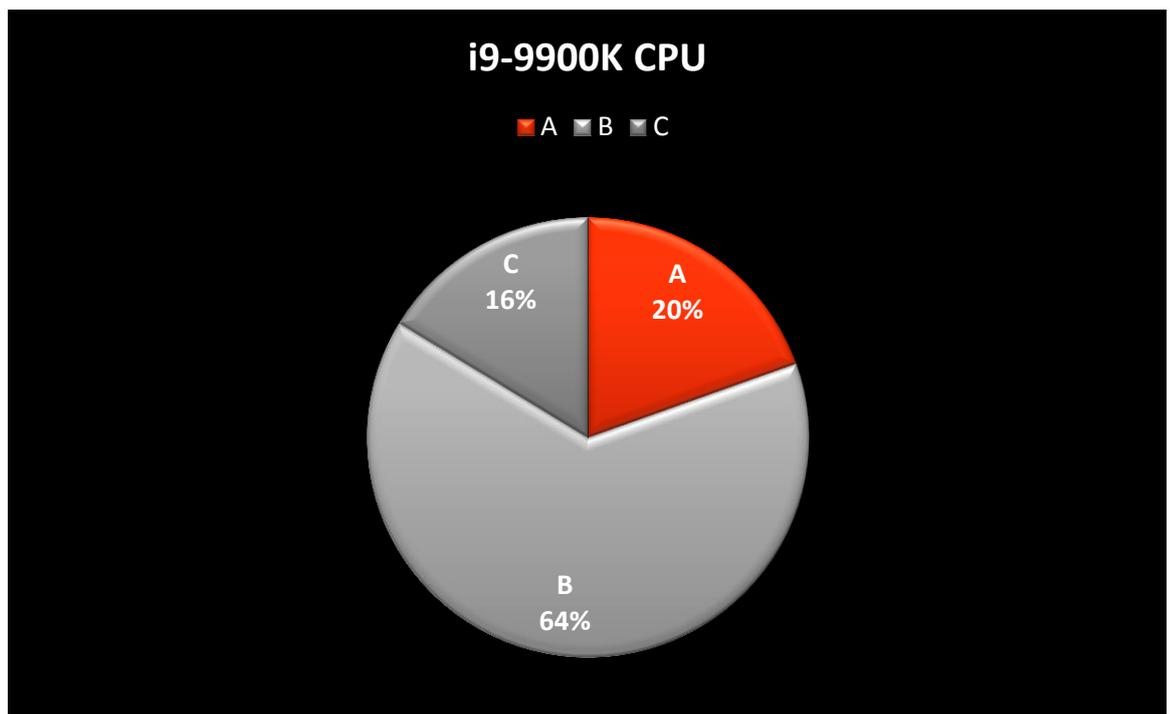


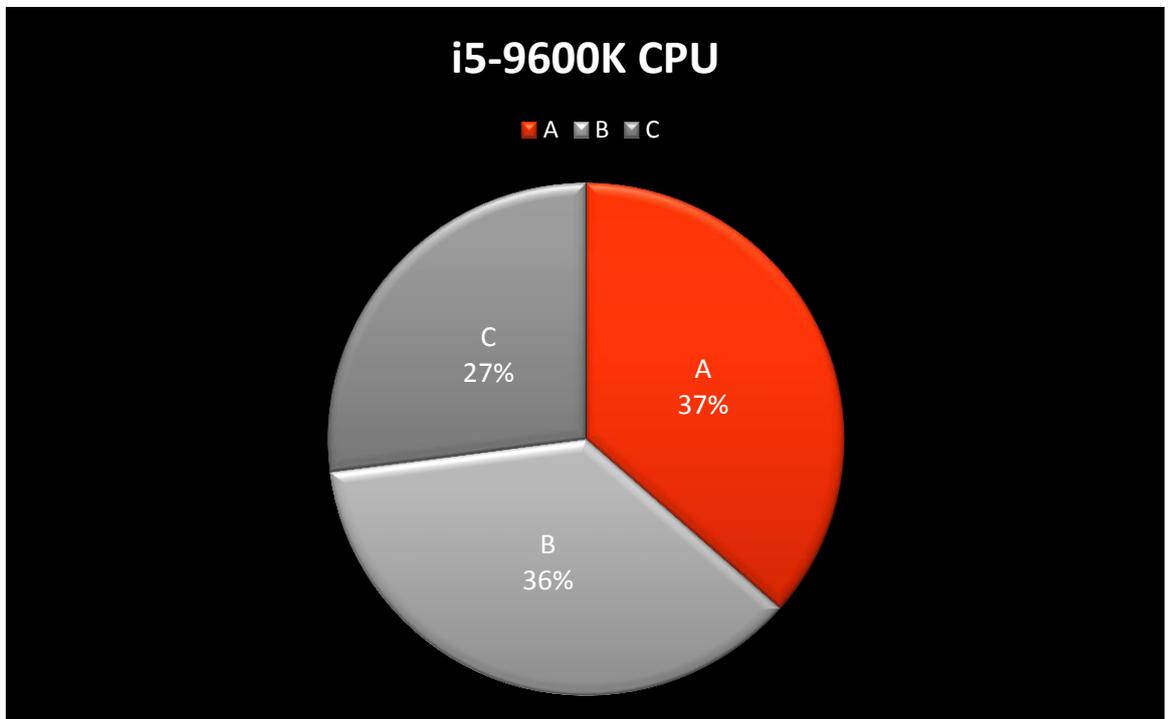
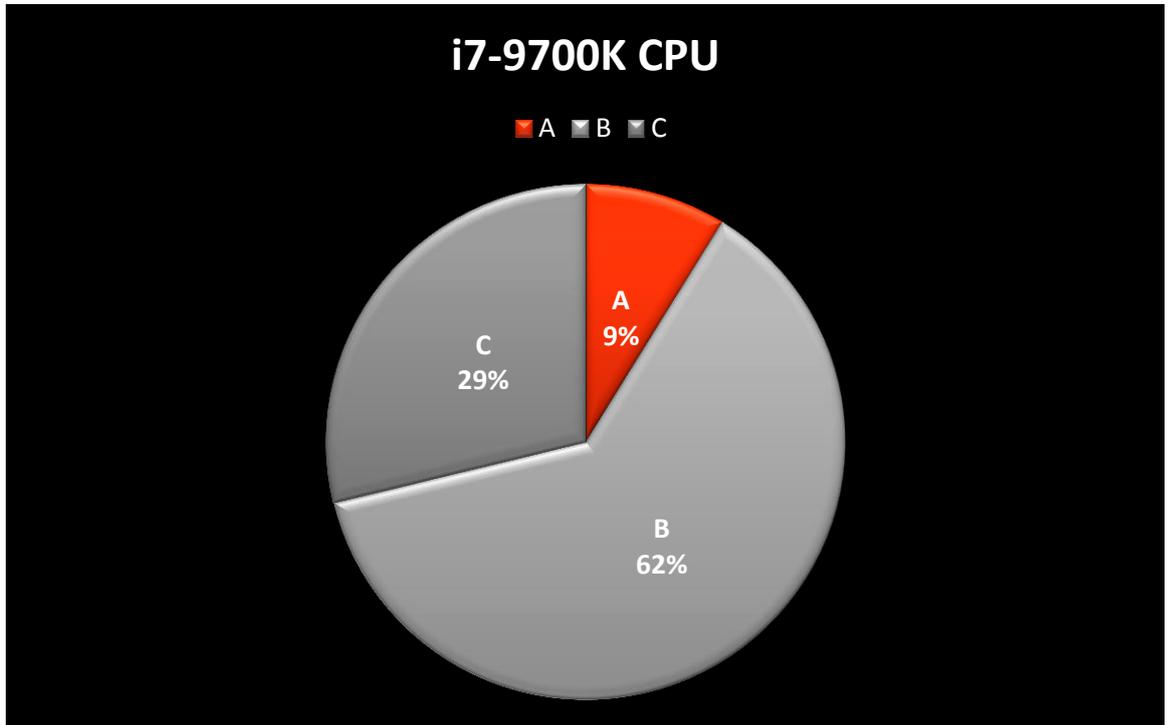


## Intel 9<sup>th</sup> Gen Processor OC capability overview

Several factors may affect your max overclocking frequency, like motherboard VRM design, MOSFET heat sink, and the most important: CPU overclocking capability. Every CPU has different overclocking ceilings. Good chips can reach higher frequency than bad chips. And good chips needs lower core voltage than bad chips.

We've binned some 9<sup>th</sup> gen processor samples we have and come out the frequency-voltage relation. We divided the samples into grade A, B, and C, according to the binning result. A is the best in overclocking, C is not good and B in between. Below graphs show the percentage of each grade. As you can see, 20% of i9-9900K is good at overclocking.

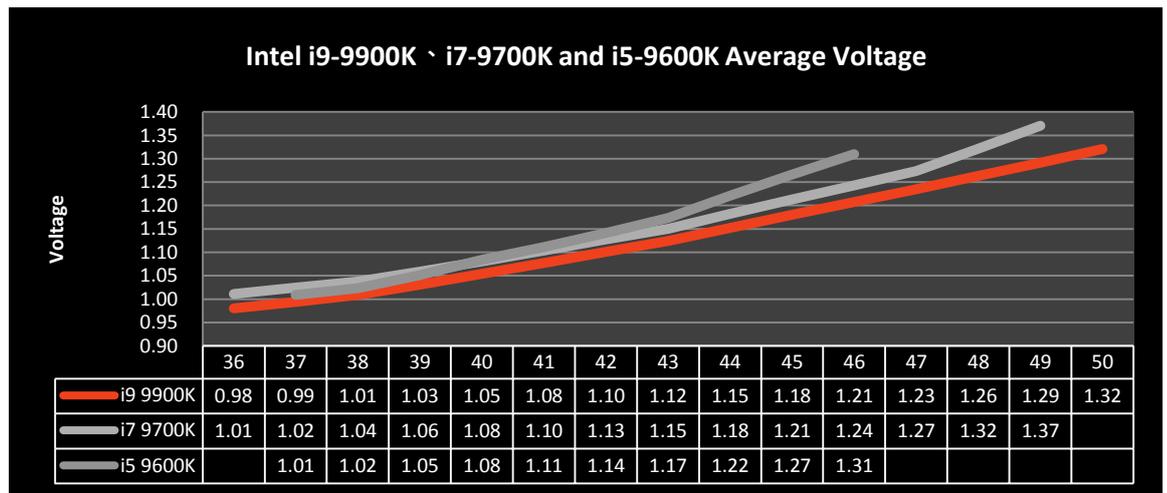




## The Frequency-voltage relation of Intel 9<sup>th</sup> Gen processors

We binned a certain quantity of Intel 9<sup>th</sup> Gen processors and below is the curve of frequency-voltage relation. This curve is based on the processors we have and thus your CPU may vary.

You can refer to this table and start with this frequency and core voltage curve. This will reduce your time of finding sweet frequency-voltage settings.



# Overclock i9-9900K to 5GHz & memory to 4000MHz

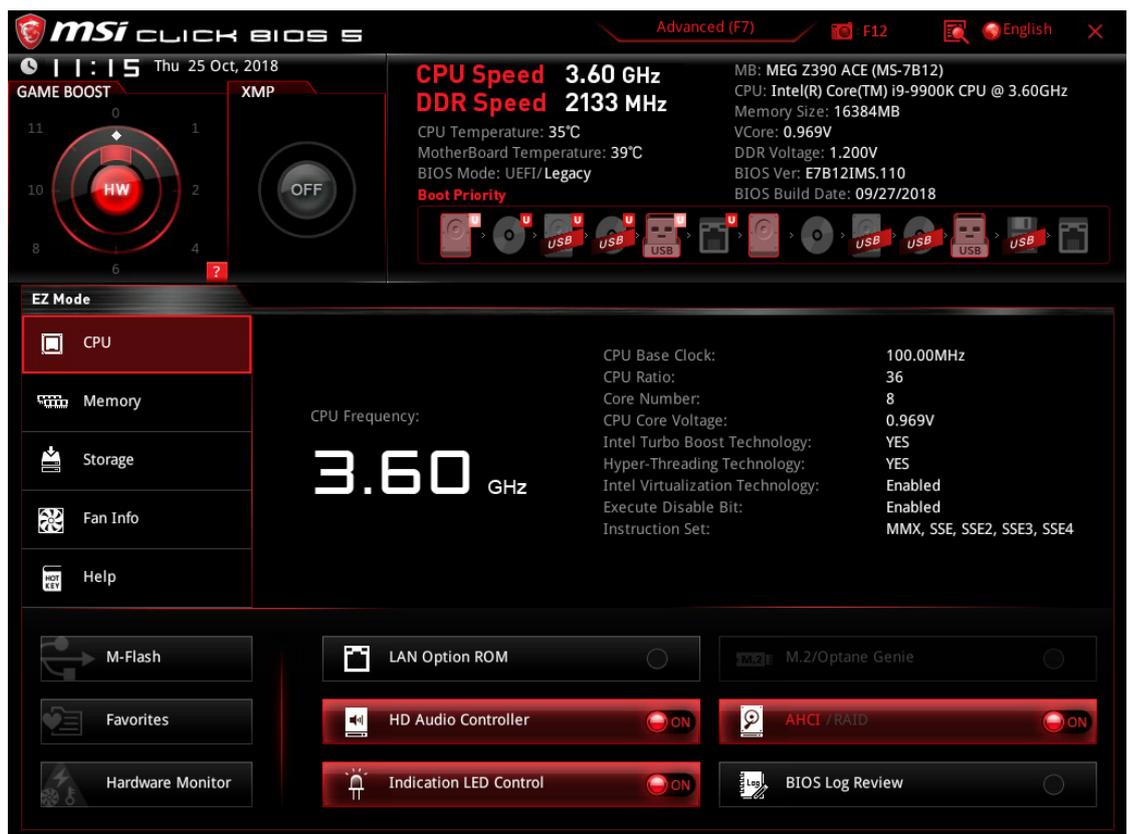
Here we'll show how to overclock i9-9900K to 5.GHz+ on MEG Z390 ACE. The same way applies to i7-9700K and i5-9600K and other MSI motherboards. We'll also show how to overclock Corsair 3600MHz memory to 4000MHz by MSI's new and exclusive "Dragon Alliance Mode".

## 1. Enter BIOS

The first step to overclock is press "delete" key to enter MSI Click BIOS.

## 2. Press F7 to go to Advanced Mode

Click BIOS offers Easy Mode and Advanced Mode. Easy Mode puts frequently used options in one page. In Advanced Mode you can find all settings. Press "F7" key to go to Advanced Mode. Advanced Mode is recommended for overclocking.



The screenshot displays the MSI Click BIOS 5 interface in Advanced Mode (F7). The top bar shows the date and time (Thu 25 Oct, 2018, 11:15) and the current mode (Advanced (F7)). The main display area is divided into several sections:

- GAME BOOST:** A circular gauge with a red needle pointing to 11, labeled "HW".
- XMP:** A large "OFF" button.
- CPU Speed:** 3.60 GHz
- DDR Speed:** 2133 MHz
- System Information:** MB: MEG Z390 ACE (MS-7B12), CPU: Intel(R) Core(TM) i9-9900K CPU @ 3.60GHz, Memory Size: 16384MB, VCore: 0.969V, DDR Voltage: 1.200V, BIOS Mode: UEFI/Legacy, BIOS Ver: E7B12IMS.110, BIOS Build Date: 09/27/2018.
- EZ Mode:** A sidebar menu with options: CPU, Memory, Storage, Fan Info, Help.
- CPU Frequency:** 3.60 GHz
- System Settings:** CPU Base Clock: 100.00MHz, CPU Ratio: 36, Core Number: 8, CPU Core Voltage: 0.969V, Intel Turbo Boost Technology: YES, Hyper-Threading Technology: YES, Intel Virtualization Technology: Enabled, Execute Disable Bit: Enabled, Instruction Set: MMX, SSE, SSE2, SSE3, SSE4.
- Hardware Controls:** M-Flash, Favorites, Hardware Monitor, LAN Option ROM, HD Audio Controller (ON), Indication LED Control (ON), M.2/Optane Genie, AHCI / RAID (ON), BIOS Log Review.

### 3. Switch to “Expert” mode to see all OC settings

Go to “OC” page where you can see all overclock related settings. Switch “OC Explore Mode” from default “Normal” to “Expert”. Then you can see everything you need for overclocking, like CPU ratio, Memory frequency, CPU and memory related voltage.



### 4. Adjust CPU Ratio & Ring Ratio

To overclock i9-990K, the first to start is CPU Ratio. Our target is 5GHz, so just key in “50” for CPU Ratio. Then change Ring Ratio to 47. You can try your own Ring Ratio, but we suggest Ring ratio 3x less than CPU Ratio.

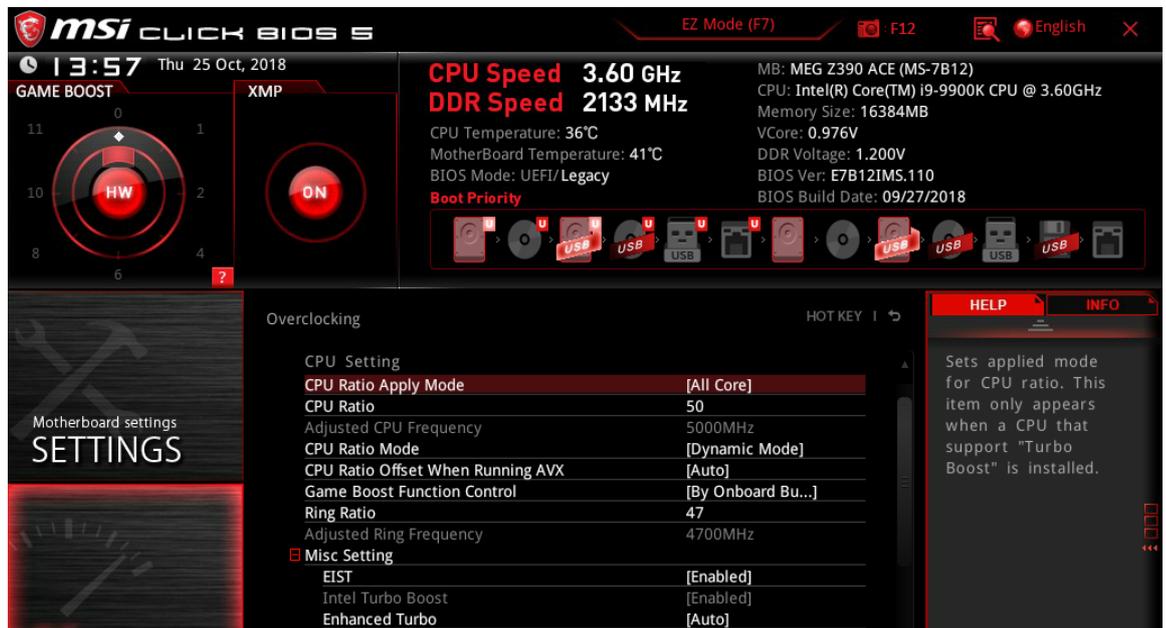
Ring frequency is the frequency of non-core parts of CPU, such as memory controller and cache. Higher Ring frequency is helpful for better benchmark performance.

*CPU Frequency = CPU Ratio  
x BCLK*

*Eg. 5.0GHz=50 x 100MHz*

*Ring Frequency = Ring Ratio  
x BCLK*

*Eg: 5.0GHz =50 x 100MHz*



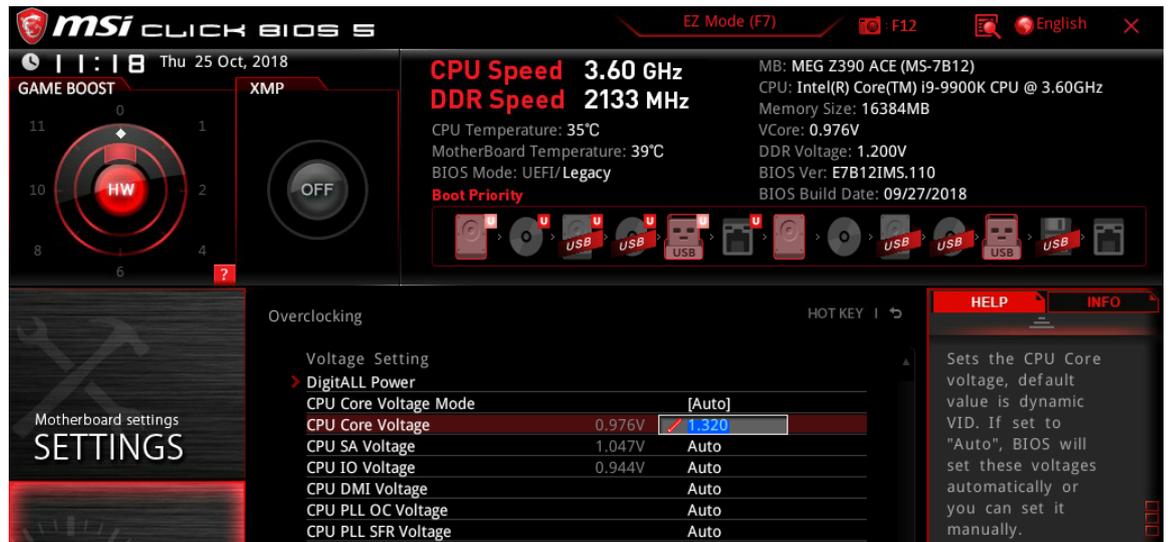
### CPU Ratio Mode

CPU Ratio Mode includes “Fixed mode” and “Dynamic mode”. In Fixed Mode, CPU frequency will be fixed either CPU is idle or under load. In Dynamic Mode, CPU frequency is dynamic depending on CPU is idle or under load. It’s up to you to choose Fixed or Dynamic Mode.



## 5. Adjust CPU Core Voltage

Then we move on to CPU core voltage. Higher voltage is needed or higher frequency. Our recommendation to is: 1.32v for OC i9-9900K to 5GHz, 1.37v for i7-9700K 5GHz and 1.43v for i5-9600K 5GHz. Each CPU needs different core voltage for stability. If you're lucky to get a good chip, you may need lower core voltage for stable 5GHz than what we suggest. You can try to lower or increase the voltage to find the best settings for your chip.



The screenshot shows the MSI Click BIOS 5 S interface. The top bar displays 'EZ Mode (F7)', 'F12', and 'English'. The main display area is divided into several sections:

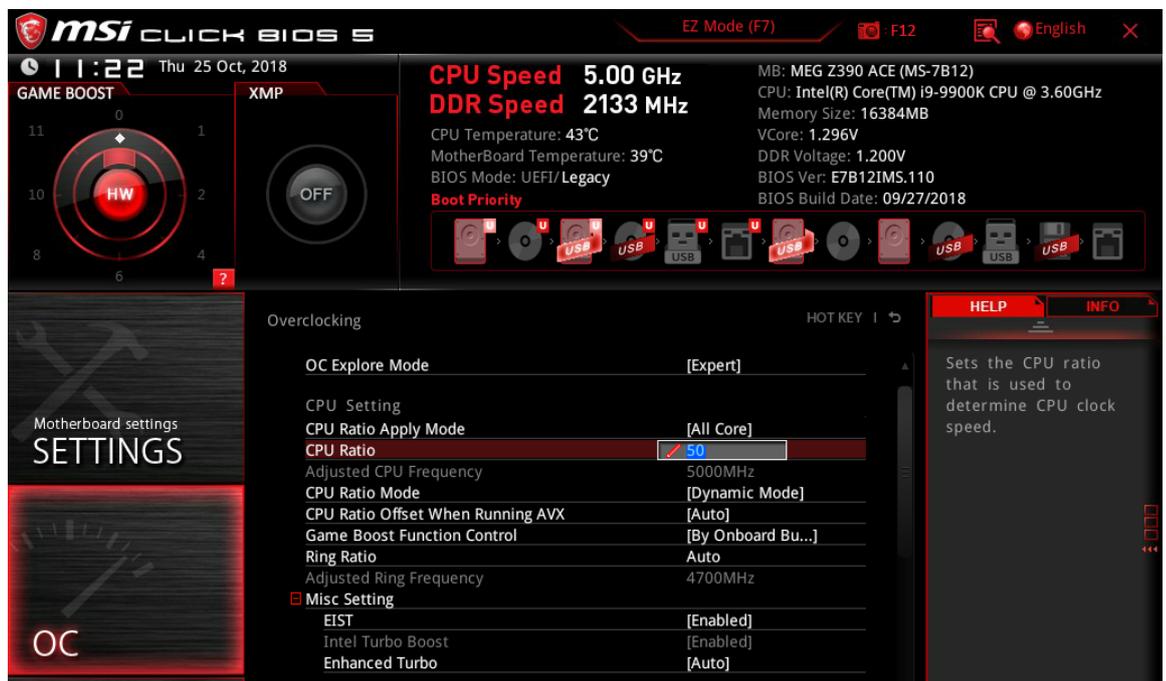
- GAME BOOST**: A circular gauge with 'HW' in the center, ranging from 0 to 11.
- XMP**: A large 'OFF' button.
- System Information**:
  - CPU Speed: 3.60 GHz
  - DDR Speed: 2133 MHz
  - MB: MEG Z390 ACE (MS-7B12)
  - CPU: Intel(R) Core(TM) i9-9900K CPU @ 3.60GHz
  - Memory Size: 16384MB
  - VCore: 0.976V
  - DDR Voltage: 1.200V
  - BIOS Mode: UEFI/Legacy
  - BIOS Ver: E7B12IMS.110
  - BIOS Build Date: 09/27/2018
- Boot Priority**: A row of icons representing different boot devices like Hard Drive, CD/DVD, USB, and Network.
- Overclocking**: A section with a 'Voltage Setting' table.

Setting	Value	Mode
DigitALL Power		[Auto]
CPU Core Voltage	0.976V	1.320
CPU SA Voltage	1.047V	Auto
CPU IO Voltage	0.944V	Auto
CPU DMI Voltage		Auto
CPU PLL OC Voltage		Auto
CPU PLL SFR Voltage		Auto
- SETTINGS**: A large 'Motherboard settings' button.
- HELP** and **INFO**: A sidebar on the right with a help text box.

*MSI BIOS automatically gives the recommended Core Voltage to your CPU, according to its overclock capability.*

### Auto Core Voltage for your CPU frequency

If you have no clue about how much CPU Core Voltage should be given for your chip, you can just leave CPU Core Voltage auto. MSI BIOS will automatically determine the recommended Core Voltage according to your CPU's overclock capability. This auto Core Voltage is based on MSI testing data and it varies with CPUs. It's lower for a good chip and higher for a not-so-good chip. You can increase or decrease the voltage later according to your result of stability test.



### CPU Core Voltage Mode

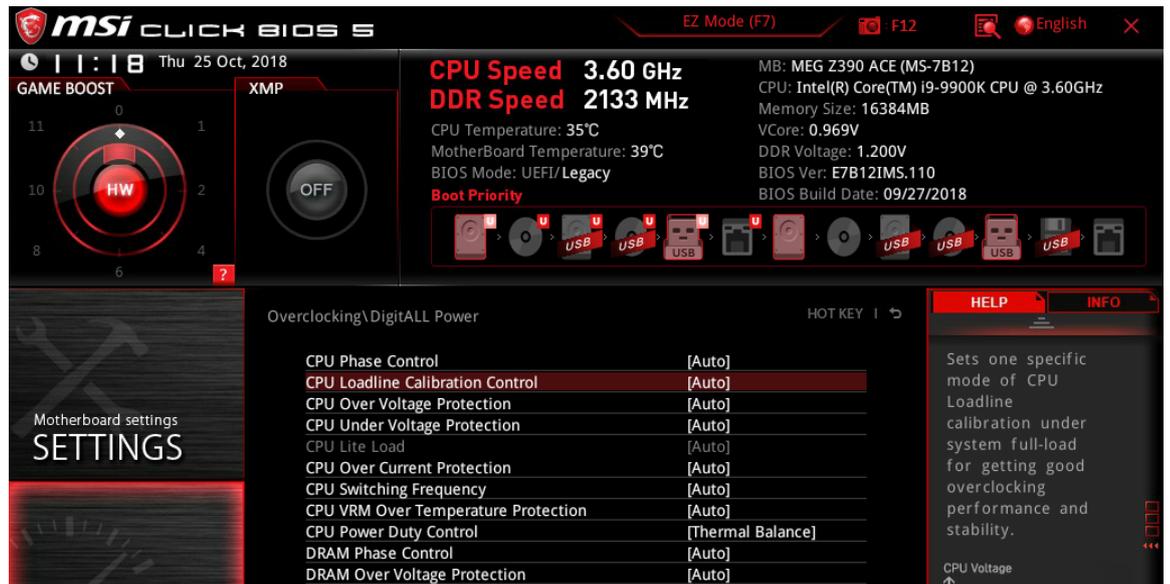
There are 5 CPU Core Voltage Modes available. Override Mode keeps core voltage fixed either the CPU is idle or under load. Adaptive Mode will change the voltage, depending on either it's idle or under load. Offset Mode adds the offset voltage you set to default voltage.

Override+Offset Mode is the Override Mode plus Offset voltage, while Adaptive+Offset implies Adaptive Mode plus Offset voltage. "Override Mode" is recommended for overclocking. It's also the BIOS default mode for overclocking.



### CPU Loadline Calibration Control

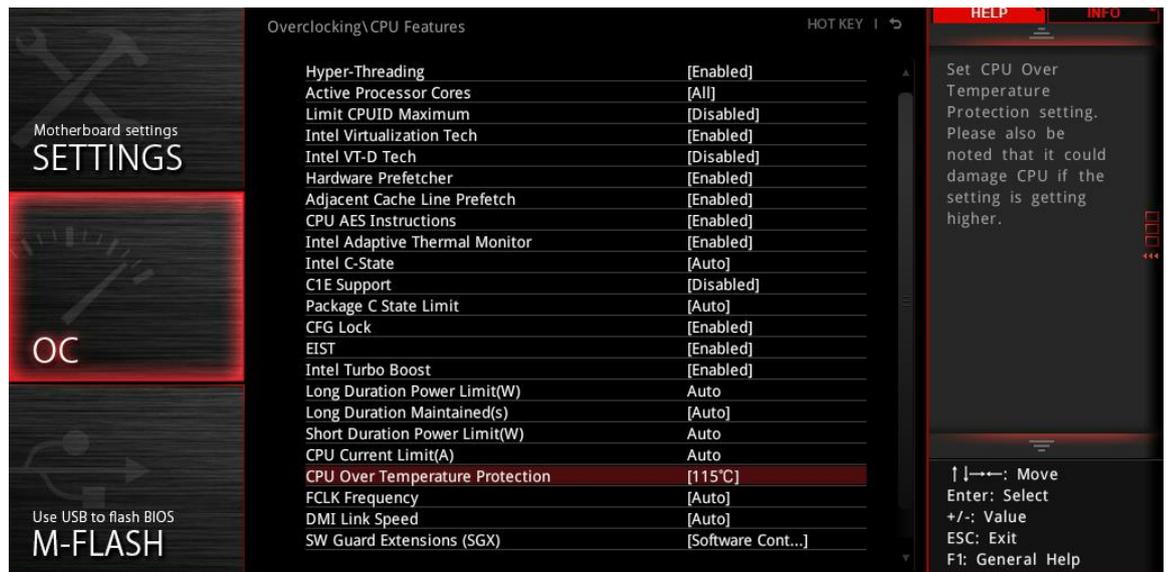
It's CPU behavior that when the CPU load increases, the core voltage decreases. This situation is called "Vdroop". "Load line" is the line or relation of load and voltage. Vdroop may cause system unstable when you're overclocking. CPU Loadline Calibration is to improve Vdroop and is helpful to better stability. It's suggested to keep CPU Loadline Calibration "Auto" (Mode 3). BIOS will apply the optimized setting when you're overclocking.



*If you plan to stress test i9-9900K with AVX workload, it's recommended to increase CPU throttling temperature to 115°C*

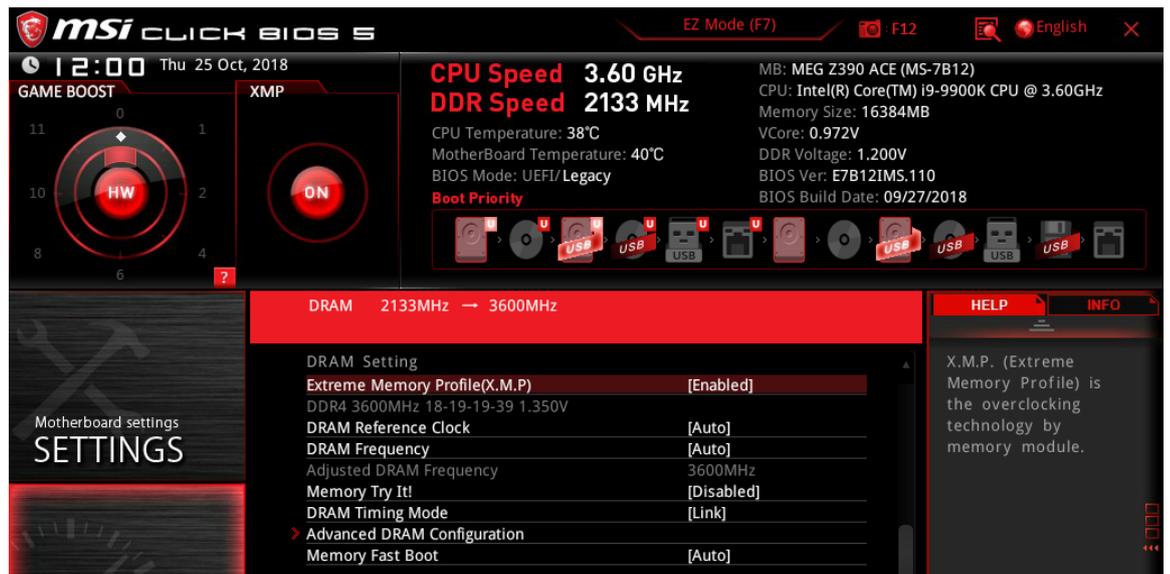
### Increase CPU throttling temperature

If you'll do stress test with AVX-compliant Prime95, you may need to increase CPU throttling temperature. You can set the temperature to 115°C to make your CPU not throttle until it hits 115°C.



## 6. Overclock your memory by loading XMP

XMP is the quick way to overclock your memory. It's also easy to do: just enable Extreme Memory Profile (X.M.P). When XMP is enabled, you can see the XMP frequency and main timings. Here is the example of Corsair CMK16GX4M2B3600C18. Its XMP profile is 3600MHz 18-19-19-39.



*MSI exclusive Dragon Alliance Mode can push your memory higher than XMP frequency.*

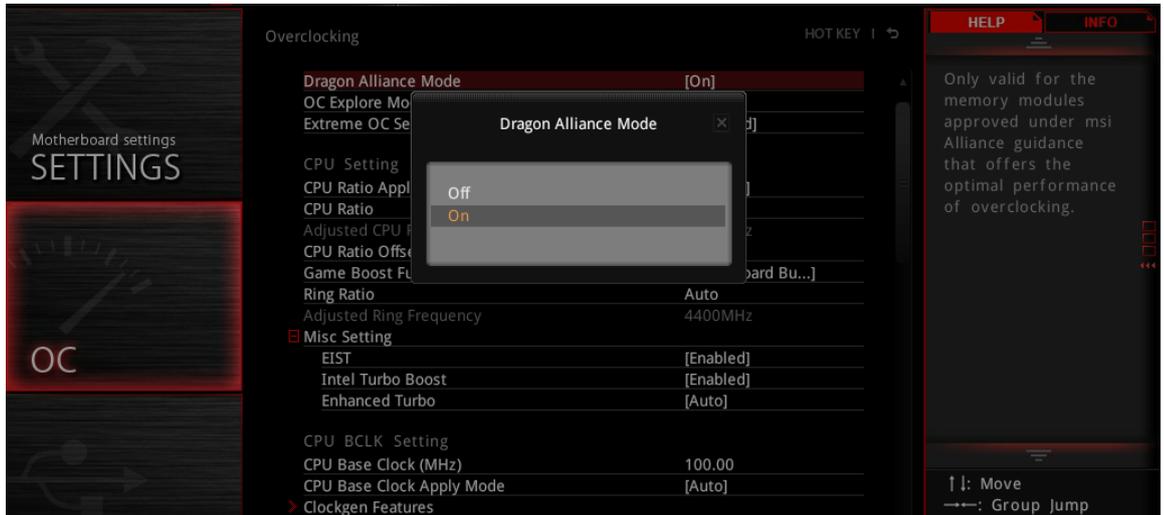
### 7. Push your memory higher by MSI exclusive Dragon Alliance Mode

MSI has worked with memory maker like Corsair, ADATA, KLEVV and more, to push more on memory. Dragon Alliance Mode can push your memory higher than XMP frequency. The Dragon Alliance profile is worked out together by memory maker and MSI.

If your memory kit is supported by Dragon Alliance Mode, you can see the option in BIOS. Turn it on to load the profile. That's it!

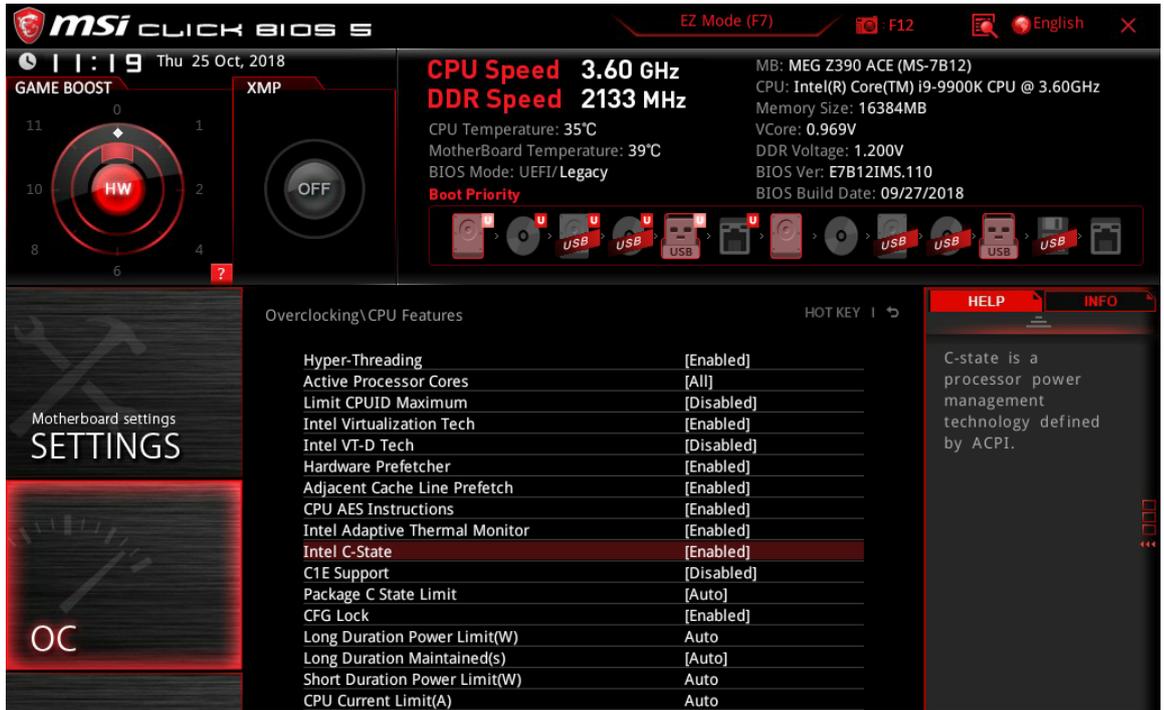
Take Corsair CMK16GX4M2B3600C18 for example, Dragon Alliance Mode will push it to 4000MHz, faster than its 3600MHz XMP.

If you don't see this option, it means your memory kit is not supported.



### 8. Disable Intel C-State

Intel’s power management features like C-State, Package C-State may have negative effect on overclocking stability. It’s recommended to disable C-State for better stability.



### 9. Done! Press F10 to save and exit

After finishes all the settings, press F10 to save the settings you modified and exit. When you press F10, there's a pop-up message notifying the settings changed. Check again and press "yes" to exit BIOS and apply changes.



## Stability test for your overclocked system

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After finishing the overclock settings in BIOS, it's time for stability test. If the system is stable then you can try to push higher frequency to get better performance. Or you can try to lower the voltage to decrease the CPU temperature. If the system is not stable, then try to increase the core voltage or lower CPU frequency.

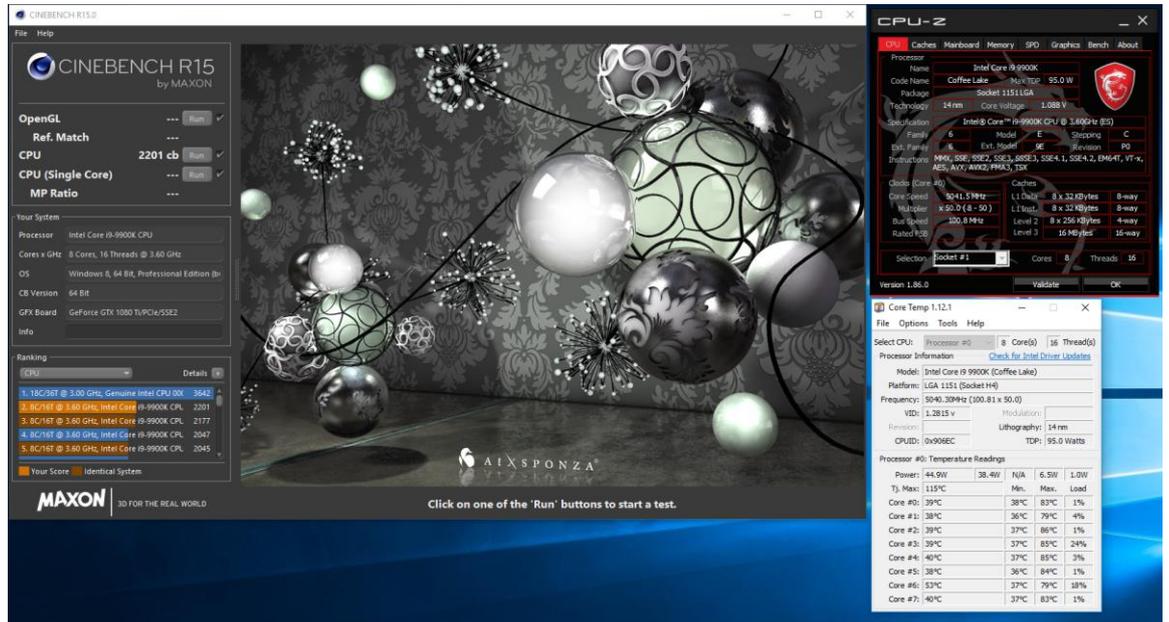
### Suggested software for stability test

Here is the list of some frequently used software for stability test:

- CPU-Z to check the CPU frequency
- Core Temp or HWiNFO to check CPU temperature and CPU package power
- Cinebench R15 to do quick stability test and check performance scaling
- AIDA64 or Prime95 v26.6 (non-AVX) / Prime95 v27.9 (AVX) for stress test.

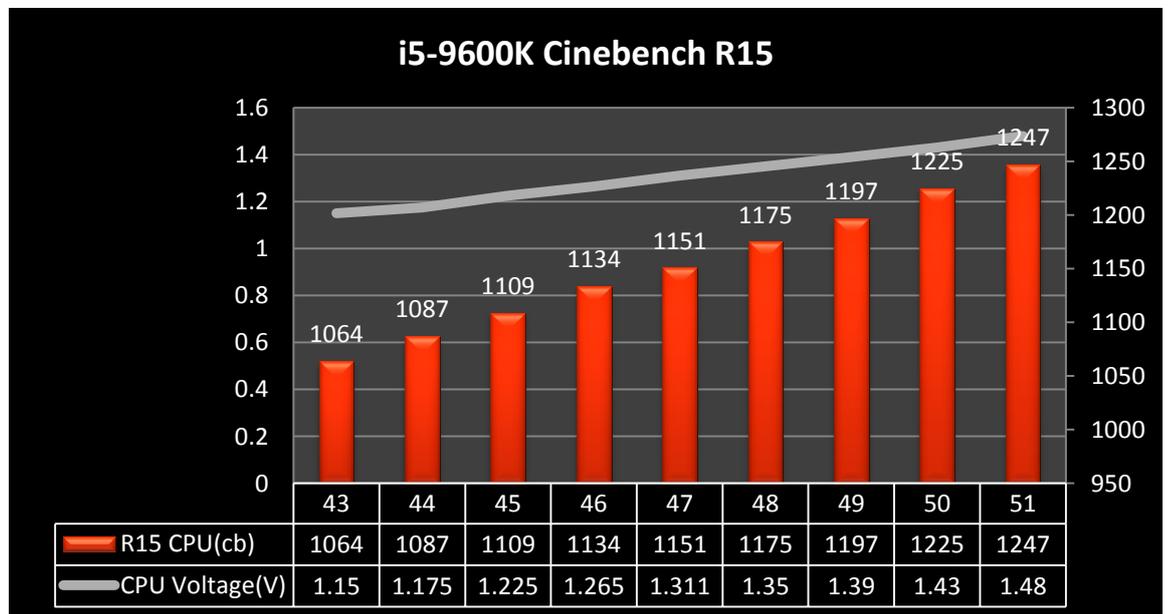
### Stability test with Cinebench R15

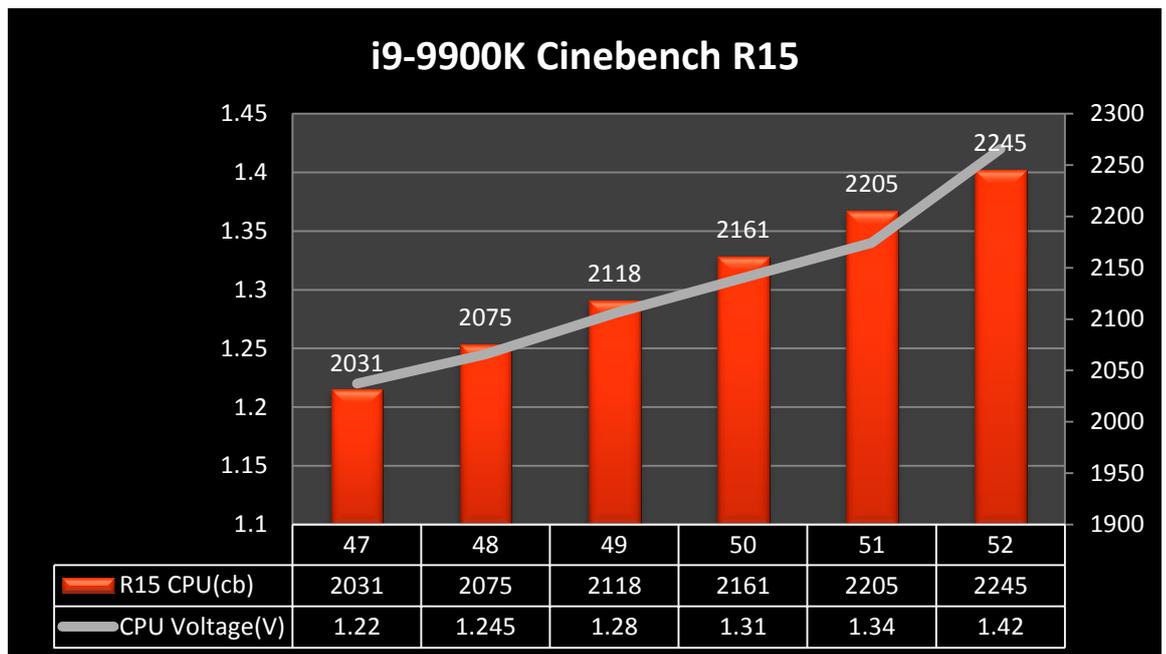
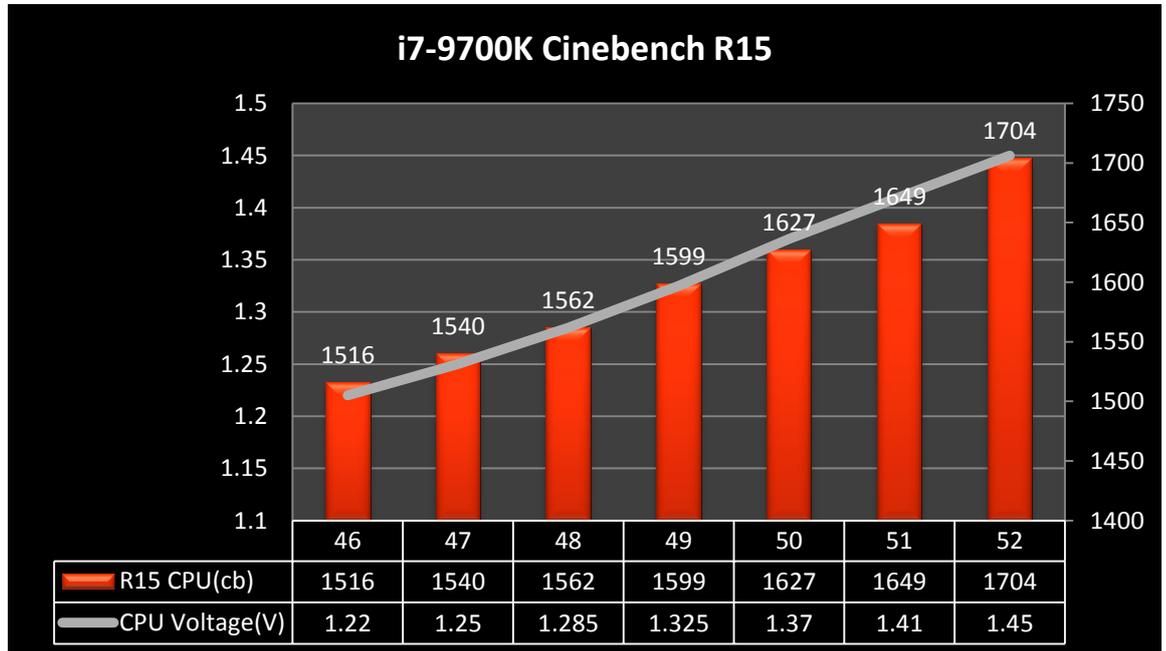
Cinebench R15 is a useful tool to do quick stability test. CPU-Z is suggested to check if your CPU Ratio setting in BIOS works. Core Temp is to check CPU temperature. If the system is not stable, you can try to increase Core Voltage or decrease CPU Ratio. If the temperature is above 90°C, it's recommended to lower the Core Voltage. Here is an example of a stable 5GHz i9-9900K + 4000MHz memory system.



### Cinebench R15 performance scaling for 9000 series processors

Here is the Cinebench R15 performance scaling for i9-9900K, i7-9700K and i5-9600K. You can refer to this data to check if your CPU performance scales with CPU frequency.





i9-9900K 5.1GHz & memory 4000MHz achieved.

### 5.1GHz i9-9900K/4000MHz memory is stable with non-AVX Prime95

If your system is stable with Cinebench R15, then you can go further with Prime95 stress test. Prime95 provides three stress test modes: Small FFTs, In-place large FFTs and Blend. Small FFTs stress much on CPU and generates lot of heat. Blend test some of everything and lots of memory.

Prime95 that's newer than v26.6 supports AVX (Advanced Vector Extensions), and it's very heavy workload. AVX also generates lot of heat. If you don't have a customized liquid cooling system or you don't want to stress your CPU too much, Prime95 v26.6 is suggested for stress test.

Our i9-9900K tested can do 5.1GHz @ 1.33v and passes Prime95 v26.6 Small FFTs stress test for more than 1 hour. The Corsair memory is overclocked to 4000MHz by Dragon Alliance Mode. The CPU starting temperature is 93°C with Corsair H150i PRO RGB 360mm liquid cooler.



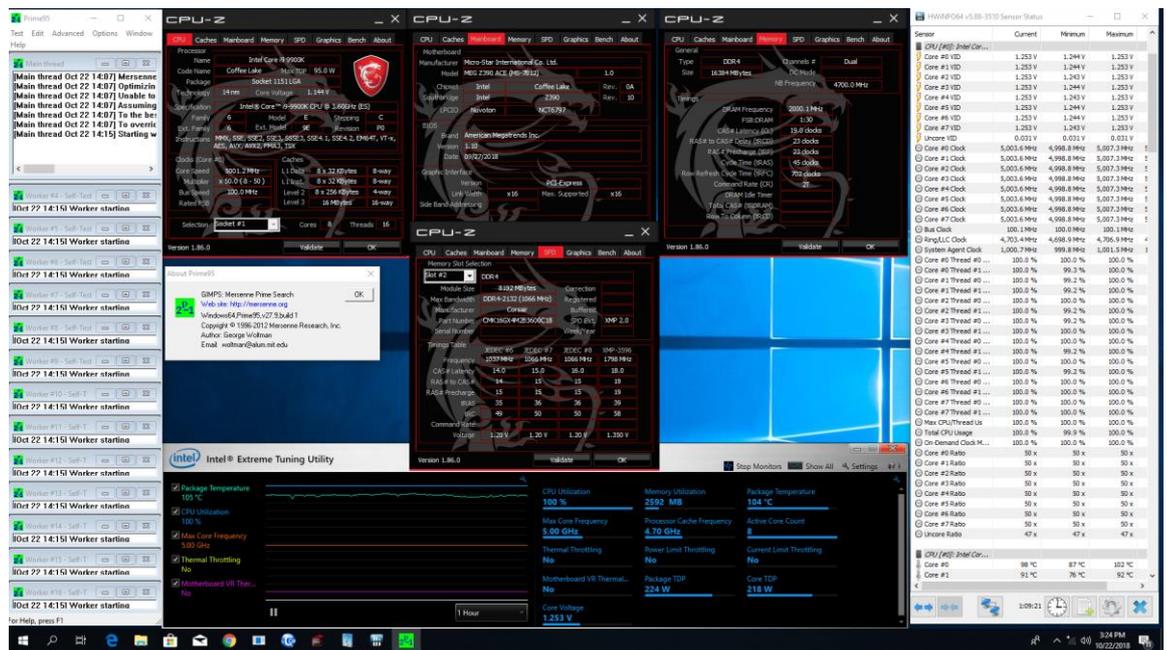
The screenshot displays a Windows desktop with several monitoring applications running. On the left, a Prime95 window shows the 'Small FFTs' test mode with multiple worker threads starting. In the center, multiple instances of CPU-Z are open, displaying system information for an Intel Core i9-9900K CPU running at 5.1 GHz with 1.33V voltage. On the right, HWINFO64 shows sensor data for the CPU, including temperatures (93°C) and voltages (1.33V). At the bottom, Intel Extreme Tuning Utility (XTU) is visible, showing system metrics like CPU utilization (100%), memory usage (2595 MB), and package temperature (93°C).

i9-9900K 5GHz &  
memory 4000MHz is  
stable for AVX  
Prime95 stress test.

### 5GHz i9-9900K/4000MHz memory is stable with AVX Prime95

Prime95 v27.9 is AVX capable and it's a big challenge to the CPU cooler. You may need a customized liquid cooling system to keep the CPU temperature under 100°C.

This test is done with Corsair H150i PRO RGB 360mm and the CPU temperature goes to 104°C after 1-hour stress test. It's not throttling because we increase the CPU throttling temperature to 115°C.



Test configurations	
CPU	Intel Core i9-9900K
Motherboard	MEG Z390 ACE BIOS v1.10
Memory	CMK16GX4M2B3600C18 8GBx2
Graphics card	MSI GeForce GTX 1080 Ti GAMING X
SSD	Samsung 860 PRO 512GB
CPU Cooler	Corsair Hydro Series H150i PRO RGB 360mm Corsair Hydro Series H110i GT 280mm Thermaltake Water 3.0 Ultimate be quiet! Silent Loop 360mm Cooler Master MasterLiquid ML240R RGB
Operating system	Windows 10 PRO x64 1803